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EDITORIAL

Five years ago, in March 1952, the *Journal of the Canadian Association of Radiologists* had the privilege of publishing a group of five original papers which were destined to make history in the advance of radiology. Those articles introduced, at once, most of the fundamentals of ionizing radiation therapy with kilocurie Cobalt^{60} teletherapy units.

The physical characteristics of the radiation in Cobalt^{60} beam therapy were discussed by H. E. Johns, including depth dose data and isodose distribution. Room protection measurements for Cobalt^{60} teletherapy units were determined by W. R. Dixon, C. Garrett and A. Morrison. Further, D. T. Green and R. Errington offered their considerations in the design of the Cobalt^{60} beam therapy equipment. The clinical possibilities of the Cobalt^{60} beam unit were considered by T. A. Watson. Some influences and advantages of Cobalt^{60} beam therapy were envisaged by Ivan Smith.

The late A. J. Cipriani, who had played an important part in the promotion and development in Chalk River of compact powerful sources of Cobalt^{60}, introduced, in a special editorial, this Canadian achievement in the field of radiological science. He then predicted that these powerful sources would "not only supplant radium beam therapy" but would also "compete with X-ray machines in the 2,000,000 to 3,000,000 volt region".

A few years have sufficed to prove that Dr. Cipriani's anticipation not only came true but is even being surpassed. Teletherapy units are now available which are using smaller sources of Cobalt^{60} of the order of 500 - 600 curies. These are made to be used at shorter treatment distances, generally at 50 cms. focus-skin distance. Under these circumstances, the distribution of radiation in the tissues is such as to be equivalent to the distribution obtained with conventional x-radiation. At the same time, the clinical advantages of high energy radiation are being retained: less skin reaction, less absorption in bone, and less radiation sickness. Other sources of radiation for beam therapy units will soon be available on the market, using Caesium^{137}; their energy levels at 0.66 Mev. is such that Caesium^{137} units may be expected to replace 200 - 500 Kv X-ray machines.

Five years have now passed since the first Cobalt^{60} beam therapy units ever built were utilized in Canada for the first time, about the end of October, 1951, in the cities of London and Saskatoon. Today, the Editorial Board of this Journal has the pleasure of presenting the medical world with the first five-year reports on the clinical applications of Cobalt^{60} teletherapy units to the treatment of diseases, largely neoplastic. Obviously the group of articles being published in this issue must be considered only as preliminary reports. The clinical experience already acquired can only indicate certain trends.

The trends already observed indicate that the main advantage of Cobalt^{60} radiation, utilized for teletherapy purposes, lies in the treatment of deep-seated lesions which could hardly ever be treated adequately with conventional X-ray therapy. Such advantage is not related to any special virtue of Cobalt^{60} radiation. It is directly related to the greater penetrating power and the scattering in a forward direction of Cobalt^{60} radiation, which are physical properties common to any high energy beam of radiation of identical quality. Thus, excessive tissue reactions which were forcing discontinuation of X-ray treatments may be avoided.

It is too soon to determine as yet to what extent the apparent physical and radiobiological advantages, to be derived from the high energy Cobalt^{60} sources, might improve results in the treatment of neoplastic diseases over those already obtained with conventional x-radiation in the 0.2 to 0.3 Mev. range. Time might tell, but not necessarily so. Such comparison will prove to be extremely difficult, even if series of comparable and identical cases could be treated alternately with Cobalt^{60} or with 200 - 300 Kv radiation, strictly without selection.

If this accepted concept is true, that the same dose of ionizing radiation should produce the same biological effects, irrelevant of the quality of the beam, we doubt very much that significant differences may be observed in favour of Cobalt^{60} over 200 - 300 Kv radiation. From crude clinical observation it seems to us that doses of Cobalt^{60} radiation 15 to 20% greater would be required to induce the same biological effects as we have been accustomed to observe with conventional x-radiation.

We would like to suggest that one way, perhaps, of improving the results in the treatment of neoplastic diseases with Cobalt^{60} radiation beam might be to deliver considerably larger doses than it has been possible to deliver in general with conventional x-radiation. This might apply particularly to tumours which have shown a certain degree of radiosensitivity but yet have presented little evidence of high radiocurability.

An impulse was unquestionably given by the development of the first Cobalt^{60} beam therapy units. The utilization of sealed radioactive sources of high energy and high intensity in compact sources is increasing in importance in the field of external radiation beam therapy. The radiation therapist must learn to use his new tools to the best advantage of his patients. These new tools might influence to some extent the results of radiation therapy in the treatment of neoplastic diseases. Further improvement will largely depend upon the skill of the radiation therapist, as a clinician, to assess each case properly. It will depend also upon his ability to correlate the biological effects to be anticipated with the physical characteristics of the most suitable source of radiation to be selected for each patient to be treated.

JEAN BOUCHARD, M.D.

Royal Victoria Hospital, Montreal.

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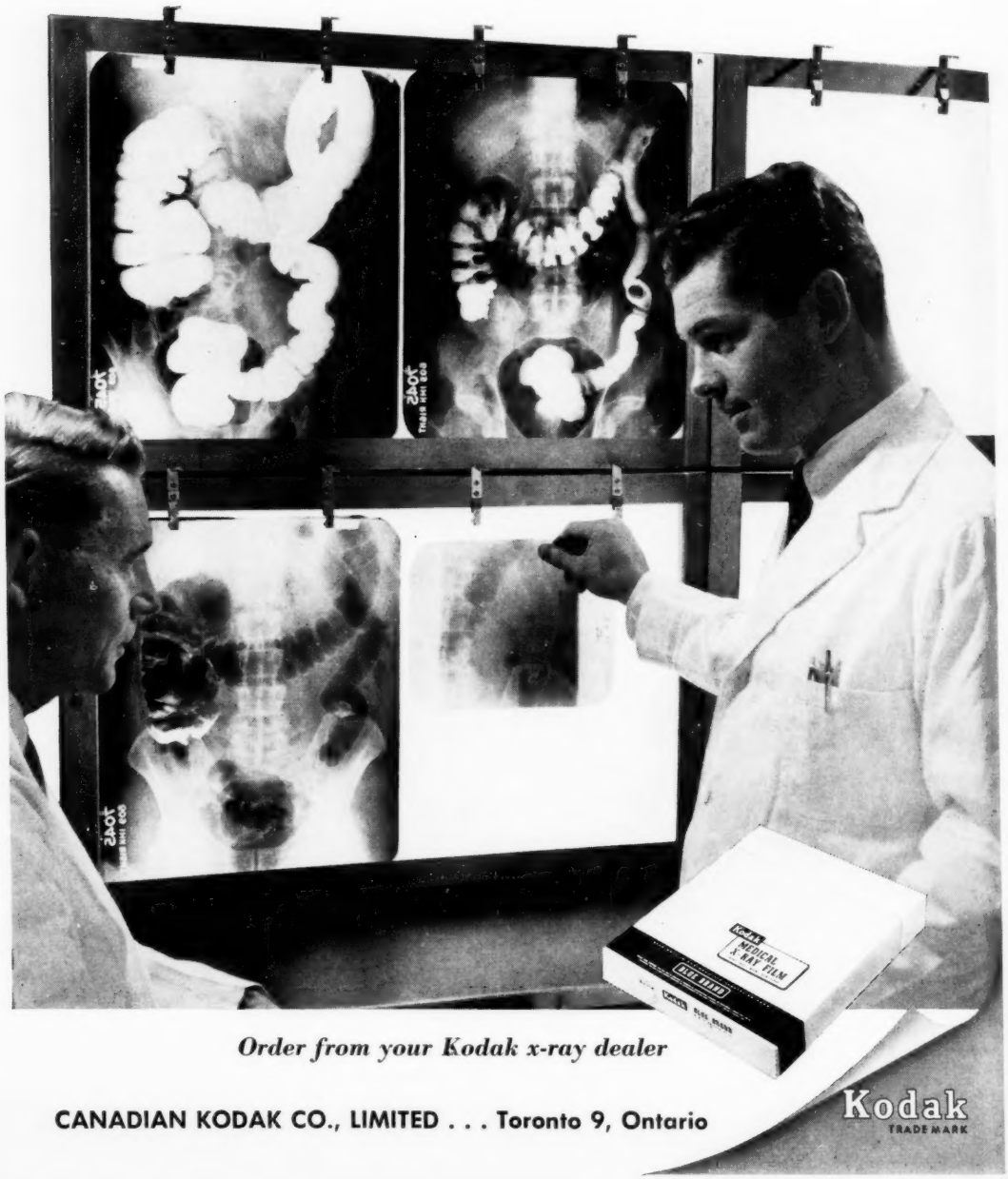

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THE JOURNAL OF THE
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CO^{60} TELECURIETHERAPY — AFTER FIVE YEARS *

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In August 1951 a radioactive cobalt telecurietherapy unit, of over 1,000 curies, was installed by the Saskatoon Cancer Clinic. Later in the year it was used in the treatment of human cancer. Since almost 1,000 patients have now been treated by this unit, it is perhaps opportune to try and assess what has been accomplished, and just what is the relative importance of this type of unit in a radiotherapy department. Although all the remarks that follow refer to Co^{60} telecurietherapy, there is no reason that they should not be applied to any other apparatus (e.g., 2 or 3 Mev. X-ray machines, 4 Mev. linear accelerators) which is also in the moderate supervoltage range, since there is no physical or biological evidence to suggest that the radiation produced by any of these means differs significantly.

The structure of the Saskatoon unit has been exhaustively described elsewhere[4]. Suffice it to say that the unit, by means of special collimating devices[5], can be made to produce any size field from 4 x 4 cms. to 20 x 20 cms., at 80 cm. source — skin distance. The unit moves up and down, forwards and backwards, and rotates more than 90° from the vertical to the horizontal. Various accessory devices for beam direction and measurement of compression are provided, and there is also a revolving platform, as part of the floor, for rotational therapy. In other words, every advantage of the most flexible X-ray apparatus is matched. The output, on installation, was approximately 40r min. at 80 cms., equilibrium with scattering material being established.

Prior to the installation of this unit the radiotherapeutic armamentarium at the Saskatoon Cancer Clinic consisted of 140 KV, 200 KV and 400 KV X-ray therapy apparatus and half a gram of radium in needles and tubes, as well as a quantity of Co^{60} wire encased in gold, which could be used for moulds. A 23 Mev. betatron was also being used experimentally in certain types of advanced cancer, and radon was available from a plant operated at the University of Saskatchewan. In 1954 a 280 KV machine was installed.

From 1950 to early in December 1956, 3,957 patients suffering from malignant disease were treated by radiotherapy in the Saskatoon Cancer Clinic. Table I sets out the number of these patients treated by various methods by year. It will be seen that the total number of patients treated each year is relatively constant — varying from 523 to 597. The distribution of types of cancer treated remained fairly constant throughout this period, except that the number of small skin cancers, treated by superficial X-ray, tended to decrease in the more recent years.

A study of Table I reveals that:

(a) After 1951, when only 7 patients completed treatment, the annual number was similar for the Co^{60} unit.

(b) The number of patients treated annually on the 23 Mev. betatron remained roughly constant, with the exception of 1950. During all this period this machine was used experimentally in advanced cases only, and probably, if it were not available, these patients would have been transferred to the Co^{60} unit.

(c) The 400 KV machine ceased to be used after 1952. It will be noted that this discontinuity corresponds with the start of Co^{60} treatment. The reason for this is that any consideration, which made 400 KV preferable to 200 KV in an individual case, also made Co^{60} preferable to 400 KV. Thus, the 31 cases treated in 1952 at 400 KV would have been treated on the Co^{60} unit if full facilities had been immediately available.

(d) The 200-280 KV treated cases showed a sudden decrease in numbers in 1952. This fall, however, was not due to the diversion of patients to the Co^{60} unit, but to the fact that the routine treatment for a large group of patients (suffering from cancer of the lip) was switched from 200 KV to radon seed implant. Allowing for this change, then, the

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*Presented at Annual Meeting, The Canadian Association of Radiologists, January 13-17, 1957, Montreal.

†Saskatoon Cancer Clinic, City Hospital.

TABLE I
ALL MALIGNANT CASES TREATED BY RADIOTHERAPY BY METHOD (1950-1956)

METHOD	YEAR							
	1950	1951	1952	1953	1954	1955	1956*	TOTAL
Co^{60}		7	152	194	186	213	190	942
BETATRON	45	25	25	20	24	23	21	183
400 K.V.	100	108	31					239
200-280 K.V.	158	154	88	100	109	105	135	849
SUPERFICIAL (140 K.V.)	146	127	118	154	113	122	98	878
RADIUM**	101	102	143	129	116	126	149	866
TOTAL	550	523	557	597	548	589	593	3957

* To December 1956 only.
** Includes Intracavitary, Interstitial, or Mould Use of Ra^{226}, Em^{222}, or Co^{60} Tubes.

number of patients treated at 200 KV annually is similar, until 1956, when a rise took place. This rise was not due to any change in treatment policy, but to the transferring of some patients who would normally have been treated on the Co^{60} unit, because pressure of treatment time on the unit became acute due to steadily falling output.

(e) The number of superficial lesions treated by radiation decreased slowly in later years because of a tendency to deal with more of the early skin cancers by excisional biopsy.

(f) Our indications for the use of intracavitary or interstitial radium or radon, or of moulds, remained the same, excepting that there was a switch of early lip cancers from 200 KV to radon seed implant in 1952.

Table I demonstrates, then, that throughout the period during which the Co^{60} unit has been in use, there has been no major change in policy as to selection of patients for any individual treatment.

TABLE II
MALIGNANT CASES TREATED BY RADIOTHERAPY BY METHOD

METHOD	PATIENTS TREATED	
	1950-51	1952-56
Co^{60}	1%	32%
BETATRON	6%	4%
400 K.V.	19%	1%
200-280 K.V.	29%	19%
140 K.V.	26%	21%
RADIUM, etc.	19%	23%
TOTAL	100%	100%

Table II supports these arguments, using percentages of patients treated by various means in the two periods 1950-51 and 1952-56. One startling change is the drop in the percentage of patients treated by 200 KV-280 KV from 29% to 19% in the two periods. This is easily accounted for by the fact that, in the first period, cancer of the lip accounted for 8 points of the 29%. By subtraction, then, the comparable figures would be 21% and 19%.

The most important consideration is the selection of patients for supervoltage therapy, which, after all, is only suitable for certain cases of malignant disease, and does not, in fact, take the place of medium voltage or superficial X-rays, nor of locally applied radium or radon. All are still necessary in a properly balanced radiotherapy department so that, by a suitable choice of armamentarium, the most adequate treatment can be given to each individual patient.

The main question at issue is the discrimination in the use of supervoltage and medium voltage therapy. Most, if not all, of the differences between the two are physical in nature and are concerned with distribution of radiation in the tissues[3,7]. Thus, supervoltage radiation, compared with that of 200-400 KV provides a higher depth dose (especially where small fields are used), a lower integral dose for the same volume irradiated, much less skin reaction for the same given dose[1], and less differential absorption between bone and cartilage and other tissues. On the other hand, since medium voltage X-rays can be easily screened with lead, irregularly shaped fields can be obtained without elaborate precautions, and certain parts of the body (e.g., mouth) can be shielded when desired. Furthermore, while large fields can be obtained

at reasonable focal skin distances with X-ray apparatus, the same is not true of Co^{60} machines. Sometimes, for lesions near the surface, the lower percentage depth dose of medium voltage may be preferable, if a short distance supervoltage unit is not available.

There is a possibility that a qualitative difference in biological effect exists between the two energy ranges. This is based on the fact that the mean linear ion density produced by high energy photons is very much less than that of medium energy photons[2]. It is just possible, therefore, that, at the molecular level, a more homogeneous distribution of ionization may be obtained with supervoltage radiation, thus permitting a more truly average differential effect to obtain between cells of different sensitivities.

A very broad division of malignant disease, from a radiotherapeutic point of view, is attempted in Table III. The first subdivision "Head and Neck" includes tumours of the mouth, lip, tongue, pharynx, larynx, thyroid, salivary glands and brain. Almost all of these tumours have been treated by either Co^{60} telecuriethерapy, medium voltage X-ray or locally applied radium or radon. Cancers of the tongue, floor of mouth and lip are best treated by radium (or radon) implantation or mould since here it is easy technically to apply a high dose to a limited volume, with a rapid fall-off of dose in surounding normal structures, and at the same time use high energy radiation with its lesser absorption in bone and cartilage. Larger lesions in this region are better treated by supervoltage therapy because, compared with medium voltage, there is less chance of bone or cartilage necrosis and skin reactions are much less severe. Cobalt therapy is also preferred over 200 KV therapy for the same reasons in cancers of the larynx and pharynx. An added advantage of supervoltage in nasopharyngeal tumours is the lessened screening effect of the great masses of bone at the base of the skull. On the other hand, medium voltage therapy is usually preferred in tumours of the salivary and thyroid glands because a high depth dose is actually undesirable, in that unnecessarily severe mucosal reactions over wide areas may be produced. Tumours of the brain are better treated by supervoltage radiation because of the shielding effect of the skull and because epilation tends to be less permanent and skin reactions less severe.

"Deep" tumours — e.g., cancer of the esophagus, inoperable cancer of the lung, or large cancers of the bladder — are obvious choices for supervoltage therapy. Here, the large depth dose, the relative absence of skin reactions, the lesser incidence of radiation sickness and the lesser absorption in bone are self-evident advantages. The same arguments apply when external radiation is used in cancers of the cervix or uterus — either as a primary measure, or as an adjunct to radium treatment. In these two latter diseases our primary treatment in early cases is still intracavitary radium.

The fourth site in Table III is "Breast". This term includes primary radiation treatment of cancer of the breast, post operative radiation therapy and the treatment of recurrences. When primary radiation treatment is indicated, we prefer to use medium voltage X-ray because a large area must be covered

TABLE III

ALL MALIGNANT CASES 1952-56 TREATED BY RADIOTHERAPY BY SITE & METHOD

SITE	METHOD						
	Co^{60}	Betatron	400 K.V.	200-280 K.V.	140 K.V.	Radium, etc.	TOTAL
HEAD & NECK	145		2	59		242	448
BLADDER, LUNG & OESOPHAGUS	108	71	1	14		8	202
CERVIX & UTERUS	95	26	1			295	417
BREAST	327		7	71			405
RETICULOSES	38		4	274			316
SUPERFICIAL	23		1	9	605	92	730
MISCEL-LANEOUS	199	16	15	110		26	366
TOTAL	935	113	31	537	605	663	2884

and, when a three or four field arrangement is used tangentially, a high percentage depth dose is not of great advantage. We use the Co^{60} unit in the post operative treatment of the axilla and supraclavicular regions, with parallel opposing fields front and back. In this way a higher dose can be obtained at the apex of the axilla, the danger of bone necrosis is minimized, and skin reactions are negligible. In general distant metastases from carcinoma of the breast, when they occur in soft tissue near the surface are more suitably treated by medium voltage X-ray. When secondaries occur in bone, however, supervoltage radiation is indicated, since we are attempting to radiate the soft tissue recurrence rather than the inorganic bone. Since "bone" absorbs a far greater percentage of medium voltage X-rays than of higher energy X-rays, it has been the practise in some centres to employ the lower energy radiation. Such an argument, however, is fallacious, in that the increase of absorption in bone occurs only in the inorganic parts. It has been shown by Spiers[6] that the secondary electrons resulting from the increased absorption in bone travel only a few microns in the adjacent soft tissue. The tumour itself, therefore, actually receives less radiation, due to the screening effect of the inorganic bone, when medium voltage X-ray is employed.

The heading "Reticuloses" includes all types of lymphosarcoma, reticulum cell sarcoma, Hodgkin's Disease and leukaemias. In all of these diseases very large fields are used with medium voltage X-ray. Although the depth dose from these large fields is less than similar sized fields using the Co^{60} unit, the difference in percentage depth dose is not nearly so great as when small fields are used, for physical reasons. Furthermore, the use of medium voltage allows much greater flexibility as far as irregularly shaped fields and screening is concerned. Since the doses used with these large fields are not great, skin reactions are not a limiting factor. Hence it will be seen that most of these cases have been treated with 200 to 280 KV X-rays.

Superficial lesions have been treated largely with 140 KV X-rays. Some, however, have been treated with radium implants or moulds, depending on the site. In a few patients the Co^{60} unit was used, when cartilage was either involved or immediately adjacent to the tumour, and when a tangential arrangement of fields could be used, e.g., in the pinna or nose, such that the beam traversed the area involved only, and did not penetrate deeper parts of the body.

The miscellaneous group is necessarily fairly large and will not be discussed in detail. The same principles outlined above have been used in the selection of radiotherapeutic method.

Discussion

From the description of the types of cases chosen for Cobalt therapy, it will be seen that there has really been very little change in our radiotherapeutic treatment policy from pre-Cobalt days. The indications for local radium or radon treatment, and for superficial X-ray treatment remain virtually intact, and, in fact, the indications for external irradiation remained constant. It was from the latter group only that patients were diverted to the Cobalt unit.

The relative number of patients treated by various radiation methods is recorded simply in Table IV. It will be noted that the actual percentage of patients treated by supervoltage therapy (which, as well as those treated on the Cobalt unit, includes the few treated by 23 Mev. X-rays) was 37. If we take into account those patients whose lesions would have been better treated on the Cobalt unit, but for whom treatment time could not be found, then this figure would rise to about 40.

TABLE IV

RELATIVE USE OF EQUIPMENT

METHOD	ACTUAL 1952-56	IDEAL (Estimated)
SUPER-VOLTAGE	37%	40%
MEDIUM VOLTAGE	19%	16%
SUPERFICIAL X-RAY	21%	21%
RADIUM, etc.	23%	23%
TOTAL	100%	100%

Since no new therapeutic principle has been demonstrated with the advent of supervoltage radiation, it is doubtful that any significant improvement in five year survival results will occur. It is probable that a few extra cases will be cured, although they probably will not be numerous enough to influence over-all figures. Apart from this aspect, however, there is a tremendous gain from the point of view of technical ease in delivering a desired dose to any depth, and of comfort to the patient during and after treatment due to the absence of troublesome skin reactions, to the lesser liability to radiation sickness,

and to the lesser danger of bone and cartilage necrosis. The latter points are of considerable importance in palliative therapy, where the maximum effect to the tumour, with the minimum of discomfort to the patient, is the ideal.

We have experienced no late unexpected complications from supervoltage therapy — such as subcutaneous fibrosis or perforation of the stomach and small bowel which have been reported elsewhere — and we ascribe this fortunate state of affairs to the careful individual study of dose distribution of radiation in all cases. We have had a few instances of necrosis of cartilage after treatment of cancer of the larynx, and one case of necrosis of the jaw, demonstrating that, in spite of the lesser differential absorption of bone and cartilage at high energies, the dangers of necrosis are not eliminated.

The dosage levels we use are approximately 8% - 10% higher than those formerly used with conventional X-rays for comparable lesions (in roentgens). If, however, we convert our doses to rads, the difference decreases to less than 5% — a difference which may not be significant at the clinical level.

Summary

Radioactive Cobalt telecurietherapy, or other supervoltage apparatus, is the method of choice in approximately 40% of patients requiring radiotherapeutic treatment for malignant disease.

Lack of discomfort to the patient during and after treatment and absence of some troublesome reactions, rather than remarkable improvement of cancer cure rates, are the benefits which are likely to accrue.

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INTERIM RESULTS OF COBALT 60 THERAPY*

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An Eldorado Cobalt Beam Unit Model A was installed by the Manitoba Cancer Institute in Winnipeg General Hospital in March, 1953 and the first patient was treated in April, 1953. The source, 1200 curies of $Cobalt^{60}$, delivered approximately 32r per minute to an average sized field at 80 S.S.D. Failure of the Chalk River reactor limited the activity available at that time. The source was renewed early in 1955, the strength this time being 1800 curies, and the output approximately 48r per minute to an average sized field at 80 S.S.D. Altogether over 1200 cases have been treated since the unit was first used. Of these 1200, only a small proportion can be presented now due to many factors, notably previous treatment by other methods of radiation, too small a number of specific disease to make a series and, indeed, the time allotted for this paper. Our object was the treatment of deep seated disease with a view to either palliation or cure, or the treatment of more superficial disease where it was felt that $Cobalt^{60}$ therapy might have an advantage over more conventional methods. It should here be pointed out that we are not a Cancer Clinic but a Radiotherapy Department attached to Winnipeg General Hospital. Almost all our cases are referred after a surgeon or physician has seen them; most after they have been both seen and treated. In many instances, only such cases are referred as are considered to be inoperable. One exception to this statement is carcinoma of the cervix, which is reviewed by the Gynaecological Cancer Committee attended by a gynaecologist, pathologist and radiotherapist. The results of treating carcinoma of cervix appear in Table I.

TABLE I CERVIX

STAGE

Year	I	II	III	IV	Unstaged	Stump
1953	8: 7 alive	12: 4 alive	5: 4 alive	1: 0 alive		1: 1 alive
1954	6: 5 alive	15: 11 alive	3: 2 alive	3: 2 alive	4: 2 alive 1 alive† 1 lost	4: 3 alive
1955	7: 5 alive 1 alive† 1 lost	8: 5 alive 1 alive† 2 lost	6: 5 alive 1 alive†		1: 1 alive	1: 0 alive
1956	5: 4 alive 1 lost	11: 8 alive 2 lost	4: 1 alive 3 alive†	2: 2 alive	1: 1 alive	3: 2 alive 1 lost

alive = alive without disease alive† = alive with disease
lost = lost to follow-up.

Admittedly, carcinoma of cervix is not treated solely by the Cobalt beam, which follows the application of intracavitary radium by a modified Manchester method. It may be of interest to extract from these figures a small group of cases, too small perhaps to be significant, in which, for a short time early in 1953, a variant on the method was used inasmuch as we made no attempt to treat Point B as a separate entity. This group was given 50 mgm. of radium in the cervical canal and 20 mgm. of radium in each fornix, for a total of 33 hours in one application, the estimated dose at Point A being 4000r and Point B being 1000r. This was followed by Cobalt beam therapy to the whole pelvis, using four fields, two anterior and two posterior, angled inwards at 45° and directed by means of the "pin and arc" method. 4000 roentgens were given to the whole pelvis in three weeks.

Table II illustrates the results of the small group treated by this method.

TABLE II CERVIX 1953

Stage	No.	Alive	Alive †	Dead
I	5	5		
II	6	4		2
III	3	3		
IV	1			1

Presented at Annual Meeting The Canadian Association of Radiologists, January 13-17, 1957, Montreal.

†*Radiotherapy Department, Winnipeg General Hospital.*

TABLE III BUCCAL ASPECT CHEEK

Year	No.	M.	F.	Average Age	Extremes	Average Survival	Extremes (months)	Dosage	
1953	5	4	1	67.4	56-80	37.4+	35+-39+	6000r (4-5 wks.)	All alive Female has tumour present. Surgery done on one male after radiation failure.
1955	2	2			74-79		10+-13+	3500-4600r (3½ wks.) 4000-4800r (4 wks.)	Probable recurrence Resection Jaw — tumour present
1956	2	2			68-79		3+-4+	5700-6000r (6 wks.) 6000-6500r (6 wks.)	Probable recurrence Had Rn seeds twi (/48 & /51 & Ra mould /55, all elsewhere.
LATE									
1953	2	2			71-73		14-10	5700-6500r (4 wks..) 4000r (4 wks.)	After incomplete surgery Insufficient X-ray elsewhere 1 yr. before.

TABLE IV RECTUM

Year	No.	M.	F.	Average Age	Extremes	Average Survival	Extremes	Dosage	
1953	9	7	2	55	49-63	8 mos.	1-36+ mos.	2-3000r in 2-3 wks.	1 alive
1954	10	7	3	61	30-75	5 mos.	days — 12 mos.		None alive
1955	9	7	2	62	32-75	9 mos.	1-24+ mos.		1 alive
1956	9	4	5	54	37-65	6 mos.	2+-10+ mos.		2 dead — 2 lost 5 alive

Buccal Aspect of Cheek

This small group is illustrated by Table III.

It may be seen that the best results were obtained in 1953. All of these cases were fairly late inasmuch as the tumour was large although no actual node involvement was present on examination. In 1953 the tumour dose, as can be seen from the table, was 6000r, the maximum tissue dose being 6500r. The single field was applied at an angle and a back pointer was used in order to direct the beam to include the whole lesion but to miss the opposite parotid in an endeavour to avoid a completely dry mouth. Those of the 1953 patients still surviving with no evidence of tumour have as a post-radiational syndrome only two complaints. One is some partial dryness of mouth, easily relieved by chewing gum or eating food, the other a definite loss of mobility of the temporo-mandibular joint, although there is no difficulty in eating food provided it is not too hard. None of the patients feels that this complaint is a serious one.

Carcinoma of the Rectum

This is a group which has obtained considerable palliation. All of the patients listed in Table IV were referred after abdomino-perineal excision had been carried out and disease had been found to be still present in the pelvis. In most cases actual fungating tumour was growing through the perineal scar. All patients had relief of pain for varying periods and in nearly all, the tumour although relatively radioresistant, regressed markedly. Life was made very much more comfortable for all of them. In all the patients in this table the tumour was described pathologically as an adenocarcinoma, grade 2.

Carcinoma of Larynx

As may be seen from Tables V and VI, the number of palliatively treated cases is twice the number of radically treated cases. Carcinoma of larynx is relatively uncommon in Manitoba and it is even more uncommon for an early case, early enough to be cured by radiotherapy, to be referred to our department. In the palliative cases, with only one exception, all of the patients had metastatic tumour in one or both cervical lymph node regions. All patients were treated with two lateral opposing fields, which gave a more or less uniform tumour dose throughout the whole area. One interesting case is the 37 month survival in Table V. This patient had a proven carcinoma of pyriform fossa, with proven metastatic tumour in one cervical region. After treatment, as far as could be ascertained clinically, both the primary tumour and the cervical node secondaries disappeared completely and did not recur. However, two and a half years after his initial treatment he developed multiple metastatic lesions in both lungs and those, although they responded favourably initially to radiotherapy by the Cobalt Unit, eventually increased and caused his death. The palliative cases in Table V are not classified as either extrinsic or intrinsic laryngeal lesions. Most of them were so far advanced that an accurate classification was difficult. The radically treated laryngeal tumours in Table VI responded much as might have been expected. With one exception, a patient who died five months after treatment, all are alive with no evidence of tumour, the survival time varying from 13 months to 23 months.

TABLE V PALLIATIVE LARYNX 1953 - 1956

No.	M.	F.	Average Age	Extremes	Average Survival	Extremes	Dosage
12	11	1	62.3	38-76	9.4 mos.	1-37 mos.	5-6000r 5 wks.

TABLE VI RADICAL LARYNX 1954 - 1955

No.	M.	F.	Average Age	Extremes	Average Survival	Extremes	Dosage
6	6		66	48-76		5-23 mos.	5-6000r 5 wks.

TABLE VII BRONCHOGENIC

Year	No.	M.	F.	Average Age	Extremes	Average Survival	Extremes	Dosage	
1953	20	20		64.2	46-83	5.8 mos.	3 yrs. 6 mos. — 2 wks.	1800-6000r	
1954	31	28	3	61.5	46-76	8 mos.	2 yrs. 9 mos.+ — days	1200-5000r	2 alive 2 yrs. 9 mos. (5000r) 1 yr. 10 mos. (5000r)
1955	19	16	3	60.5	38-75	6.4 mos.	1 yr. 6 mos.+ — days	2000-6000r	3 missing from follow-up 1 alive 1 yr. 6 mos. (3000r)
1956	26	24	2	63.6	38-84			1800-5000r	10 alive 1 mo.+—9 mos.+

TABLE VIII BLADDER — Radical

Year	No.	M.	F.	Average Age	Extremes	Average Survival	Extremes	Dosage	
1953	4	4		70.9	63-78	12 mos.	3-31 mos.	4-5000r	
1954	7	6	1	66.6	53-76	15 mos.	2 alive 4-33+ mos.	4500-6000r	Average total survival
1955	7	5	2	66	62-70	8 mos.	4-11 mos.	4-7000r	11.5 mos.
1956	8	8		70.4	56-85			4-6000r	

Palliative

1953	8	7	1	65	55-73	9.6 mos.	1-36 mos.	V A	1 alive after 3 yrs.
1954	17	11	6	68	38-83	5.6 mos.	days— 29 mos.	R I	1 missing Average survival
1955	2	1	1		64-81	3 mos.		E D	6 months.
1956	3	3		61	48-75				

Bronchogenic Carcinoma

Table VII illustrates the survival of patients with bronchogenic carcinoma and an attempt has been made to estimate the minimum and maximum doses given in any one year. Undoubtedly those who have lived longest had a larger dose given but not all those given a large dose lived very long. In other words, results are more or less comparable with results of more conventional types of therapy. One expected advantage, however, of the Cobalt Unit was that therapy, if palliative, could easily be repeated without gross skin change.

Carcinoma of the Bladder

Table VIII illustrates the results in treating carcinoma of bladder radically and Table IX results of treating bladder tumours palliatively.

Again, it is necessary to point out that most of these patients were referred because the tumour was inoperable, or had previously been operated upon and had recurred, or the patient was unfit for operation. Very few early tumours were treated.

We have not attempted to form any conclusions from the study of only three years' experience of treatment. We have been impressed with the Cobalt Beam's usefulness as a palliative instrument in cases for which conventional X-ray therapy would not have been so useful.

A COBALT^{60} STUDY IN ORAL CARCINOMA AFTER FIVE YEARS*

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Oral carcinoma, unlike cancer of certain sites such as larynx and lung, requires more than a 2 or 3 year follow-up study period to be of any significant cure rate value. Fully cognizant of this fact we simply have surveyed our small oral group, in an effort to classify or substantiate impressions we have gained since substituting Cobalt^{60} beam therapy for conventional X-ray in a relatively comparable group of oral cancer.

It should be clearly understood that even to date, with few exceptions, we have not substituted Cobalt^{60} beam therapy in treating the early lesions satisfactorily amenable to radium needle or radon seed implant. Furthermore there is little to be gained by analyzing the pitifully hopeless stage 4 group. Our analysis, therefore, is compiled mostly from those cases treated by radical Cobalt^{60} dosage, in size beyond the range of mould or implant, on whom in the X-ray era we would have prescribed radical external irradiation, either by small field beam direction technique or by using fields of moderate size.

The purpose of this thesis, therefore, is not statistical but to record, after 5 years experience with the stationary Model A Cobalt^{60} unit (A.E.C.), certain impressions which for the most part have encouraging significance.

Table 1 lists the total oral carcinoma group treated by irradiation during the entire study period from 1952 to 1955.

TABLE No. I

CASES OF ORAL CARCINOMA TREATED BY RADIATION (1952-1955)

Radium or Radon Seed Implant	33
Deep X-ray Therapy	10
Cobalt^{60} Beam Therapy	79
Total	122

Table II records the number of oral cases treated by radical and palliative Cobalt^{60} respectively; while *Table III* indicates the distribution of lesions by site treated radically, i.e. with dosage prescribed for cure.

TABLE No. II

ORAL CARCINOMA TREATED BY COBALT^{60} BEAM THERAPY (1952-1955)

Radical Therapy	50
Palliation	29
Total	79

TABLE No. III

ORAL CARCINOMA BY SITE TREATED BY RADICAL DOSAGE COBALT^{60} BEAM THERAPY. (1952-1955)

Buccal Aspect	7
Palate and Upper Alveolus	5
Floor of Mouth and Lower Alveolus	17
Tonsil and Fauces	14
Tongue	7
Total	50

The first impression is to the effect that: (1) RADIOGRAPHIC EVIDENCE OF INVASION OF THE MANDIBLE BY TUMOUR GROWTH IS NOT NECESSARILY A CONTRAINDICATION TO COBALT^{60} BEAM THERAPY. Cases with obvious clinical exposure of bone are excluded from this study. Four cases are included which revealed, on admission film, definite X-ray evidence of mandibular invasion. All 4 patients experienced not only complete regression of tumour but early total repair of overlying mucosa. One patient, aged 86, died of intercurrent disease without evidence of cancer 28 months following treatment. The remaining 3 are without pain, disease, clinical recurrence of fistula, 18, 45, and 54 months following treatment. Two detailed examples are cited as follows:

Mr. S. H. #53 39. age 62. This patient gave a 3 month history of soreness in the floor of the mouth. Examination revealed a 5 x 3 cm. ulcerating lesion involving the left lower alveolus extending on to the floor of mouth and the buccal mucosa. A clinically malignant submental node was recorded. The patient was treated using parallel opposing 7 x 7 cm. fields, the tumour dosage being 6500r in 17 treatments over 24 days. A severe fibrinous mucosal reaction was present on completion of treatment and the skin was brick red. The following week the patient was admitted to hospital for nursing care. The mucosal reaction subsided very slowly and healing was not complete until 5 months had elapsed. An X-ray taken on January 6, 1953, prior to treatment showed "a destructive lesion involving the anterior part of the body of the left mandible". A further X-ray taken on April 25, 1956, demonstrated that, "the sharply defined area of bone destruction in the anterior portion of the left horizontal ramus has been partially repaired by new bone formation". On December 6, 1956, there was slight telangiectasia of the mucosa at the site of the original lesion with a depression of the mucosa over the bony defect of the left mandible but healing was perfect.

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Figure 1. Case #55/493

Radiograph, taken prior to Cobalt^{60} treatment, shows an extensive defect consistent with neoplastic invasion of the mandible. Radon seeds are for tumour localization.

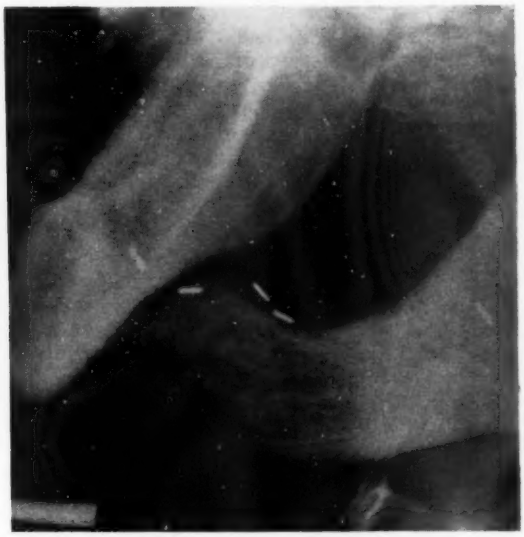

Figure 2. Case #55/493

Radiograph, taken 20 months after treatment, shows regeneration of bone at the site of previous bone absorption and there is now no evidence of osseous abnormality.

Mr. G. McL. #55/493. age 81. The patient gave a history of soreness in the mouth for 1 month. Examination revealed a 4 x 4 cm. malignant ulceration of the buccal aspect of the left cheek involving the left lower alveolus and the floor of the mouth. A clinically positive submandibular node was noted. The patient was treated using a single 11 x 9 cm. field delivering a tumour dose of 6300r in 5 weeks. A mild fibrinous reaction appeared during the third week but by completion of therapy the fibrinous reaction had disappeared. The skin showed only a dry peeling reaction. The tumour regressed rapidly and by the end of the third week had almost disappeared. The tumour regression was complete before the end of treatment and the skin reaction had subsided within 1 month. An X-ray taken on March 22, 1955, prior to treatment, showed "an extensive defect consistent with neoplastic invasion of the alveolar aspect of the horizontal ramus of the mandible on the left side". (Fig. 1.) A follow-up X-ray taken on December 5, 1956, showed "no evidence of bone destruction." (Fig. 2.) At present the mucosa is perfectly healed with no evidence of the effects of radiation. There is no bony defect at the site of the bone invasion.

We submit this first observation as further evidence against the teaching of certain centres that invasion of the mandible is a contraindication to radiotherapy. In our own Clinic, it is Cobalt^{60} first, and surgery in the event of complications.

The second observation is that (2) RECURRENCE OF DISEASE SUBSEQUENT TO X-RAY THERAPY HAS BEEN SUCCESSFULLY TREATED BY COBALT^{60}.

Table IV records details.

TABLE No. IV

TREATMENT OF RECURRENT DISEASE
(FOLLOWING X-RAY THERAPY) BY RADICAL COBALT^{60} BEAM THERAPY (1952-1955)

Alive with no disease ..... 4 cases

Site	Cases	Survival	T.D.	Time	Field Size
Floor of mouth	1	48 mos.	6000r	4½ wks.	12 x 10 cm.
Tonsil	2	48 mos.	5500r	3 wks.	7 x 7 cm.
		48 mos.	4300r	2½ wks.	5 x 5 cm.
Tongue	1	42 mos.	5500r	3 wks.	10 x 7 cm.
Died of disease ..... 1 case					
Buccal mucosa	1	4 mos.	4700r	3 wks.	10 x 8 cm.
					Total 5 cases

In this series of 50 radically treated cases there were 5 cases indicated in *Table IV* who had been previously treated elsewhere with X-ray therapy. Of the 4 surviving cases, 3 are not only alive, but are without complications. The fourth patient had an extensive carcinoma of the floor of mouth, invasion of the mandible by tumour, previously heavily treated on two occasions with X-ray therapy. At present he is alive with necrosis of the mandible 48 months following treatment.

It is notable that no attempt was made to deliver an exceptionally high tumour dose in any of the cases, nor was any attempt made to protract the treatment beyond 4½ weeks.

Our third observation is to the effect that (3) ADJACENT SOLITARY LYMPH NODE INVASION IF INCLUDED IN THE TREATMENT FIELD SHOWS FAVOURABLE INITIAL REGRESSION. Nine of the 50 radically treated cases had clinically positive solitary lymph nodes sufficiently close to the primary disease to be included in the treated volume. *Table V* sets out the patients with solitary lymph node involvement along with identification of the primary site. Bronchopneumonia was the cause of death in one case and autopsy showed that there was no evidence of residual malignancy.

TABLE No. V

PATIENTS WITH SOLITARY LYMPH NODES INCLUDED IN TREATED VOLUME-RADICAL COBALT^{60} BEAM THERAPY (1952-1955)

Alive and well			7 cases
Floor of mouth	2 cases	45 months	
		16 months	
Tongue	2 cases	42 months	
		24 months	
Upper Alveolus	1 case	35 months	
Tonsil	1 case	24 months	
Buccal mucosa	1 case	18 months	
Died of disease			1 case
Tongue		15 months	
Died of other causes			1 case
Lower Alveolus		4 months	
		Total	9 cases

None of these cases had surgery following therapy, although it was considered initially in each instance, and naturally all are still being followed carefully at short intervals. All nodes except one have either completely regressed or are regarded as clinically inert. This is an extremely interesting and indeed a surprising group worthy of extended study. As a minimum the results would seem to waive the urgency for early block dissection where the status of the primary is indeterminate.

At the present time it is our belief that (4) THE OPTIMAL TUMOUR RESPONSE LIES IN THE 6000r TO 7500r RANGE DELIVERED IN FOUR TO SIX WEEKS. Our early dosage ambition was 5000r to 5500r to tumour in 3 weeks. This is often achievable yet only too frequently with anxiety to both patient and therapist. In an effort to limit extreme early mucosal reaction, and retain control, as it were, of delivered tumour dosage, we have adopted a standard of 1500r weekly to tumour to a prescribed 6000r. This weekly dosage standard varies ± 10% according to the size of the treated volume and the age and general condition of the patient. To a treated volume suited for radical therapy, this is usually nicely tolerated in the 4 week period: yet it permits additional dosage at the same or restricted rate in individual cases where tissue reaction is low or when tumour response is slow. Even so there is the occasional annoying exception to this workable rule, all of which adds to the fascination and challenge of radiotherapy. We cite the following two extreme examples, one on either end of the scale.

Mr. E. H. #54 1024. age 54. This patient had a grade 1 squamous cell carcinoma measuring 5 x 3 cm. situated on the right lower alveolus and extending on to the floor of mouth. He was treated in a plaster cast using parallel opposing 7 x 7.5 cm. fields. The prescribed tumour dose was 6500r in 20 treatments to be delivered in 4 weeks, but after 10 treatments the daily dose had to be reduced because of a severe fibrinous reaction. Treatment was discontinued at a tumour dose of 4500r and when reaction diminished in a week, was recommenced. A tumour dose of 6500r was achieved but only after 21 treatments in 37 days. The skin reaction was moderate and did not give any concern regarding breakdown. The patient is alive and well after 26 months.

Mrs. C. A. #55 518. age 74. This case is detailed under the section on "extreme resistancy". Upon completing 7500r tumour dose in 6 weeks without tumour or skin reaction, we discontinued therapy assuming that shortly a fibrinous response would appear. It never did, even after a total dosage of 12,000r was completed in 3½ months, nor did the tumour disappear.

It is a well established fact that (5) SKIN REACTIONS ARE LESS THAN FROM CONVENTIONAL X-RAY, but how much less? How significant is it clinically? In 10 cases we used a *single* field without intervening bolus, wax or plaster. The given dose ranged from 6000r in 3 weeks to 7000r in 4½ weeks, the tumour doses ranging from 5000r in 3 weeks to 6300r in 4½ weeks. In no case was there a moist desquamation.

With *parallel opposing or tangential fields* the situation is slightly different. Of 21 cases using this technique, 10 cases were treated

without plaster, 9 cases using a plaster cast, and 2 cases utilizing a plaster cast and wax bolus. Reactions vary considerably within this group and are higher, of course, when fields are tangential, when skin lies within the tumour volume, and when plaster with or without wax is used. However, in general, moist desquamation of skin is rare.

In 19 cases a plaster of paris cast and *multiple beam directed portals were used.* The contralateral fields despite plaster showed a very light erythema. The ipsilateral skin however, if included in the tumour volume, occasionally can be moist, but its duration is short and healing is rapid. This decrease in skin reaction both in degree and duration has tangible significance for both therapist and patient. For the therapist skin tolerance and reactions no longer have a deterrent influence in achieving lethal tumour dosage. For the patient it spells comfort, albeit relative.

The sixth observation is that (6) MUCOSAL REACTIONS ARE DECIDEDLY MORE VARIABLE, i.e. less consistent in intensity for the same tumour dosage in different individuals. Although there are wide variations, one type of reaction fading into another, and indeed the exceptional patient with no fibrinous reaction, we are working under the impression that mucosal reactions fall into three categories. Our impressions are based now on a fairly standard dose rate, perhaps not comparable to others using Co^{60} beam therapy, and certainly not comparable to the dose rate customarily used with conventional X-ray therapy.

(1) It is most common, using our standard tumour dosage of 1500r per week, for the reaction to come up during the third week, quickly reach a maximum and continue unchanged through to the end.

(2) Less commonly, a more slowly appearing reaction occurs, gradually reaching fibrinous proportions during the fourth week, which is short of maximum even at the end of the fourth week. This allows scope in resistant types of lesions to push on to 7000r before a heavy fibrinous reaction will appear.

(3) Maximal reaction sometimes occurs during the third week, and on occasion earlier, and then diminishes despite the continuation of full dosage treatment.

Mucosal reaction, whilst heavy as a rule, is of much shorter duration than that of conventional X-ray therapy. The period of misery is thereby lessened. This, coupled with minimum skin effect, is of vital importance in the treatment of oral carcinoma; indeed, in the older age group it can, on occasions, be life saving.

The seventh observation is, (7) AS WITH OTHER IONIZING RAYS, CERTAIN ORAL CARCINOMA EXHIBIT EXTREME RESISTANCY. Our criteria in appraising this statement were persistence of tumour, or recurrence of the primary disease within 3 months of completion of treatment. Only 3 cases, of 50 radically treated, could be so categorized as being resistant and they are cited below. It may be argued that the dosage in case #52/1529 and #52/989 was not high. In any event the satisfactory initial tumour regression determined the stopping point and we were tricked into a sense of security. Case #55/518, on the contrary, although showing no regression and no reaction at 7500r, fooled us in that we accepted 7500r in 6 weeks as a lethal dose. Even by pushing dosage up the tumour remained totally refractory.

Mr. W. L. #52/1529. age 64. The patient presented with a large irregular squamous cell carcinoma of the right anterior pillar with extension to the floor of mouth, base of tongue and the posterior third of lower alveolus. He was treated to a tumour dose of 5600r in 3½ weeks using a plaster cast and multiple beam directed fields 6 x 8 cm. in size. A moderate fibrinous reaction was present on completion of treatment. The tumour regressed almost entirely, but became active again within three months. A radon seed implant was carried out and the tumour regressed completely leaving a necrotic ulceration. The patient died 10 months following treatment extremely debilitated.

Mrs. C. A. #55/518. age 74. When first seen this patient had a grade II squamous cell carcinoma, measuring 4 x 3 cm. involving the buccal aspect of the right cheek, extending on to the medial aspect of the ascending ramus of the mandible. She was treated using a single 8 x 7 cm. field, without plaster, to a tumour dosage of 7500r in 6 weeks without fibrinous reaction. Three weeks later, the tumour was still present, although smaller, and treatment was continued giving 500r twice weekly, to bring the total tumour dosage up to 12,000r in a total of 3½ months. At this time the tumour persisted and remained unaltered for 1 year, when following increase in size, it was excised with part of the mandible. The soft tissue alone showed viable carcinoma. The patient is alive and well 21 months after treatment.

Mr. J. M. G. #52/989. age 54. The patient presented with a grade II squamous cell carcinoma involving the entire anterior floor of mouth. He was treated using a single submental 8 x 6 cm. field to a tumour dose of 6000r in 4½ weeks with no evidence of fibrinous reaction. The tumour regressed incompletely and following observation the residual tumour was implanted using both radium needles and radon seeds. A necrosis of the floor of mouth and anterior mandible developed and the patient died of disease 27 months after his original treatment. During the latter part of his life multiple cervical nodes were controlled, as they appeared, by radon seed implant.

One senses an added safety to bone when using Cobalt^{60}. It should be thus, with the lessened coefficient of absorption; and in 43 cases radically treated showing no clinical or radiographic evidence of tumour invasion of the mandible at the commencement of treatment, no spontaneous bone necrosis has occurred. One case was precipitated by dental extraction 3½ years after therapy. Tempting though it is, we should not court disaster by leaving teeth in. Subsequent extraction may be required from bone which physiologically and histologically, if not radiographically, must show some degree of radiation osteitis.

We only wish we could make a contribution from this study to the fascinating subject of *relative biological effectiveness.* True it is less, perhaps by 15%, but tissue reaction and tumour response, our only two indicators in oral carcinoma, are simply too variable to contribute with any accuracy to the ultimate equation. Might we suggest *relative tumour effectiveness* is just a trifle different? Perhaps then we should leave the first to the radiobiologist and the latter to the therapist, requesting our physicist colleagues from time to time to keep us posted on the current value of the roentgen!

The eighth and final impression is to the effect that (8) THE CLINICAL RESPONSE THUS FAR AUGURS WELL. In surveying *Tables VI and VII* attention is drawn again to the fact that all lesions amenable to radium implant or mould are excluded: likewise all large lesions suitable only for palliation. Carinoma of fauces and tonsil, and carcinoma of floor of mouth and lower alveolus were selected for detail, primarily because they comprise the largest numbers in the series.

TABLE No. VI
CARCINOMA OF FAUCES AND TONSIL TREATED RADICALLY BY COBALT^{60} (1952-1954)

Alive and well		6 cases
	48 months - 2 cases	
	45 months - 1 case	
	36 months - 1 case	
	24 months - 2 cases	
Died of disease		4 cases
	Total	10 cases

TABLE No. VII
CARCINOMA OF FLOOR OF MOUTH AND LOWER ALVEOLUS TREATED RADICALLY BY COBALT^{60} (1952-1954)

Alive and well		7 cases
	49 months - 2 cases	
	47 months - 1 case	
	40 months - 2 cases	
	29 months - 1 case	
	26 months - 1 case	
Died of disease		3 cases
	Total	10 cases

Of the entire oral group treated radically prior to 1955, 22 of 33 patients are without disease, 24 - 54 months. Of 50 patients treated similarly, to the end of 1955 there are 33 alive and free of disease 12 - 54 months. Although these figures are not dramatic, and mindful of the fact that time has not permitted a statistical survey we are content to suggest that next to larynx, Cobalt^{60} beam therapy will find its greatest curative effectiveness in oral carcinoma.

Summary

Certain positive impressions gained after five years clinical research experience with Cobalt^{60} are listed, and enlarged upon in so far as time interval and case volume would permit. The effectiveness of radiotherapy in oral carcinoma, indeed has been expanded by Cobalt^{60}. In both general and specific ways the physical advantages of Cobalt^{60} are being reflected most favourably clinically.

LOCALIZATION OF TUMOURS FOR COBALT^{60} CIRCUMAXIAL ROTATION*

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Early in our experience with the Atomic Energy of Canada rotating Cobalt^{60} beam unit, or "Theratron", it became apparent that a beam rotating around a horizontal patient, and in a calibrated relationship to the treatment table, provided advantages which could be used to simplify the problems of localization, beam direction and dose distribution. At the same time the basic concept of a three dimensional tumour which has to be closely encased in a corresponding zone of homogeneous tumour dose could be brought closer to practical realization. This involved the development of means to work directly in terms of a volume of tumour and a volume of radiation, as opposed to the older method whereby a cross section of the tumour was simply covered by a combination of rectangular fields, which might be balanced or left unbalanced.

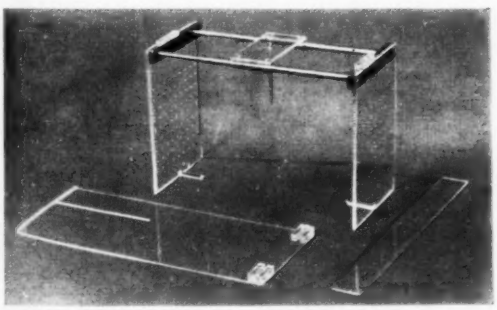

Figure 1. The localizer in basic form. Accessory grids unattached.

The production of a zone of radiation to fit the tumour volume is simplified by circumaxial rotation, in that an infinite variety of regular spheroidal or ovoid patterns result from varying the arc or opposing arcs of rotation. In addition, there is now a method[1] of predicting to a fair degree of accuracy the arcs of rotation that must be used to produce a given regular three dimensional pattern of radiation. There remains the problem of determining the shape, size and position of the tumour in three dimensions, and then placing it accurately within the volume of radiation which has been pre-determined to fit as closely as possible.

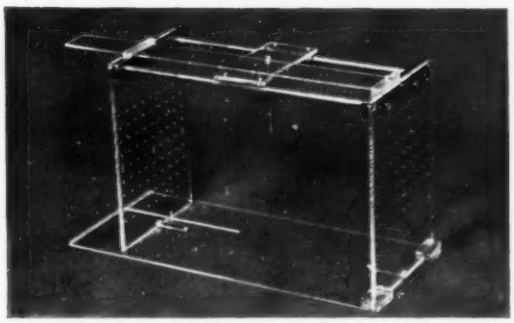

Figure 2. The localizer with the two accessory grids in position.

It is well known that the most accurate X-ray localization may be far wide of the true extent when it remains impossible to outline the microscopic edge of a tumour on a film. Although the clinical findings help considerably much art is required in deciding how much to add to the demonstrated tumour volume. Even though art still plays a large part in radiotherapy, it does not absolve us from making our technical procedures as accurate as possible. The best we can do to determine the dimensions of a tumour in three planes is to take antero-posterior and lateral views and from them plot out by deduction the dimensions in the third plane. The magnification in these views must be measured accurately, and preferably by a system which is independent of any variation in the position of the tube or the patient. For this reason, shift films were rejected as being too dependent on the accuracy with which the technician centres on the skin marker or measures the amount of shift. It was also found that

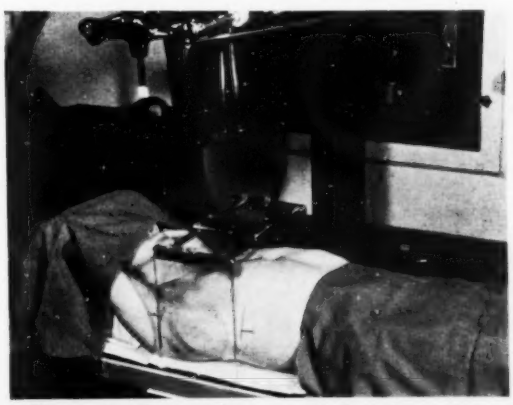

Figure 3. The patient set up for the antero-posterior film.

*Presented at Annual Meeting, The Canadian Association of Radiologists, January 13-17, 1957, Montreal.

†Ottawa Civic Clinic, The Ontario Cancer Foundation.

antero-posterior and lateral films taken under free hand conditions with markers on the skin were even more inaccurate. Plaster cast localization, besides being time consuming, is not too practical when the patient is lying down. Finally, it was the memory of a pelvimetry film covered with fine dots which gave the idea leading to the design of the present apparatus.

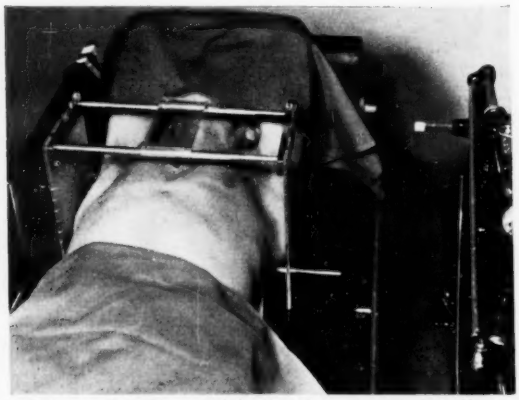

Figure 4. The positioning for the lateral film.

In essence the method developed localizes the tumour within a special bridge which can be placed over the patient lying on the diagnostic X-ray table, and replaced in exactly the same position on the treatment table. The side pieces are made of clear plastic each containing the same grid pattern of lead dots spaced 2 cm. apart. Both the centre of the grid pattern and the edges of the central line are marked by three lead dots close together, running vertically on one side and horizontally on the other. The side pieces are held at right angles to the table top by two joining rods which telescope to allow tight adjustment to the sides of the patient. Sliding along the joining rods is a clear plastic bar with a brass ring in the centre. This ring acts both as a radio-opaque marker and as a retainer for a removable steel pin. Projecting from the centre of the foot of each side piece is a 5 cm. plastic rod containing a blob of lead in the end. In this basic form the localizer is accurate for any midline tumour. As the tumour is displaced from the midline the accuracy becomes less and to restore it, at the expense of added complication, accessory grids are provided. These consist of two clear plastic plates each marked by a single line of corresponding lead dots spaced 4 cm. apart. The top plate slides through a guide screwed to the top of one side piece, just clears the central pin, and fits snugly into a blind slot screwed to the top of the other side piece. An offset peg prevents insertion the wrong way round and adds to the security. The bottom plate is held in position by two slotted blocks which fit around the lower corners of one side piece. A T-shaped brass peg is provided for insertion into a hole drilled in the lower edge of the other side piece. This peg runs in a groove cut in the bottom plate and prevents any side to side movement. When not in use the peg is kept available, and yet out of the way, at the top of the side piece.

Figure 5. Localization films of intra-cavitary radium using the complete localizer.

Figure 6. Localization films of carcinoma of oesophagus using the localizer in basic form. The ellipse outlines the lateral projection of the treated volume to the 90% isodose line.

To date it has not been necessary to use the localizer in this form for the purposes of rotation therapy. It has been used only in cases of carcinoma of the cervix for localizing the intra-cavitary radium preparatory to making up three dimensional models. Of the first 200 patients treated on the Theratron rotation therapy was used in 76 or 38%. This 38% was composed almost entirely of cases of carcinoma of the bladder, female genital organs, bronchus, rectum and oesophagus in that order of frequency. As these tumours are all close to the midline it would appear that the basic form of the localizer is sufficient in the great majority of instances. Possibly the only type of case that would require the accessory grids would be a carcinoma of the bronchus arising more peripherally than usual.

A rotation technique was used for 4 cases of pituitary adenoma and 1 case of recurrent carcinoma of the pharynx. The skull itself forms an efficient localization apparatus for the pituitary, and there is probably no virtue in rotation therapy as primary treatment for any other lesion in the head and neck. Consequently we have felt no compulsion as yet to modify the localizer for use in this region. If such modification were desired it would only involve a smaller version combined with the means to hold the head in a fixed position.

To demonstrate the method of using the apparatus the localization and initial setting up of a patient with carcinoma of the oesophagus will be described step by step. The diagnostic X-ray table is prepared by replacing all padding by a thin sheet. If the patient objects to a hard surface then it is permissible to use a ½ inch layer of foam plastic cut narrow enough that it does not overlap the body. This pad, or one exactly similar, must accompany the patient to the treatment table. It is very important that the localizer stands directly on both the diagnostic and treatment tables and not on a layer of padding. We have standardized on a single sheet folded into two and have had very few complaints. In taking the lateral film, a very finely cross hatched stationary grid is used, and it saves much time to provide a false table top, which has a slot to hold the film cassette exactly perpendicular to the central axis of the beam.

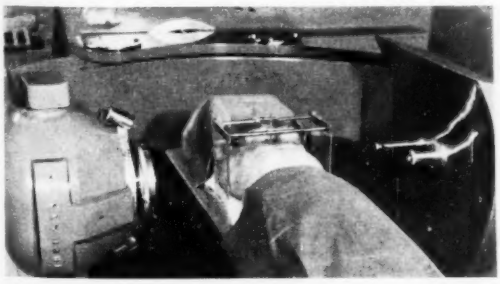

Figure 7. The initial positioning on the treatment table.

The patient is placed on the table, usually supine but occasionally prone. While the prone position is more comfortable and stable when the arms have to be raised above the head, it has the disadvantage that the oesophagus is only parallel to the table top in the supine position. Also, patients who have had a recent thoracotomy usually have difficulty in raising the arms sufficiently high above the head to assume a prone position. The localizer is opened, put over the patient so

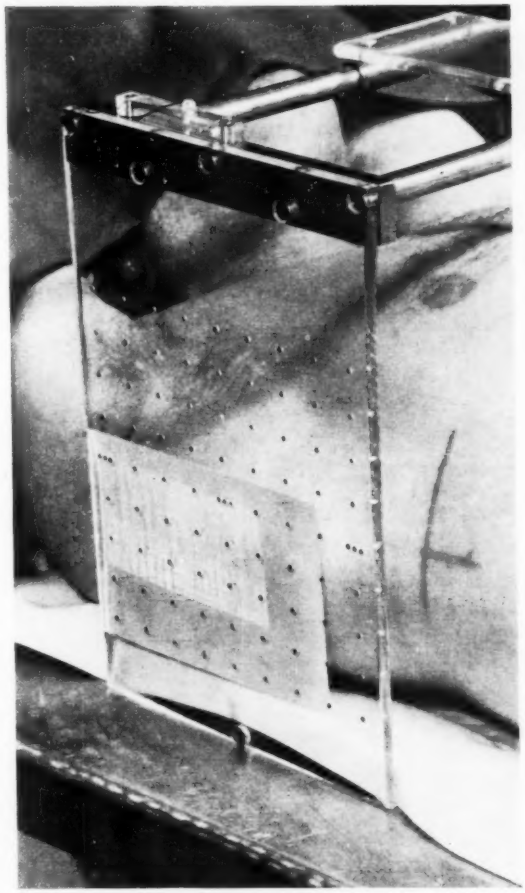

Figure 8. Adjusting the grid pattern to the light simulating the Cobalt^{60} beam.

that the tumour is within the confines of the grid pattern, and then closed for a snug fit at the sides, care being taken that the projecting plastic rods are underneath the sheet. The next step is to measure the separation of the side pieces and position the sliding bar exactly midway between. The telescoping rods could be scaled for this purpose, but a ruler does as well. This measurement is recorded on the X-ray requisition form. Having positioned the localizer with the patient in a stable, comfortable position, the pin is dropped through the brass bush in the sliding bar and the point where it meets the skin is marked with gentian violet. Skin marks are also made along the edge of each side piece with a cross mark at the level of the centre line of the grid pattern. When we come to replace the localizer on the treatment table, the positioning is controlled in the lateral direction by the separation measurement, in the super-inferior direction by the skin marks

along the edges of the side pieces and in the antero-posterior direction by gravity, provided the patient is lying on a firm surface. Rotation of the patient is controlled by the skin mark underneath the pin and by the cross marks at the sides. As the patient is lying down in exactly the same position as when the marks were applied, and is not required to change position during the time the films were taken or during treatment, the skin marks can be relied upon. Lateral and antero-posterior films are taken just after the patient swallows a mouthful of thin barium. No special precautions are necessary, apart from standardizing the tube height at 40 inches, and remembering to remove the pin from the sliding cross bar when the antero-posterior film is being taken. The usual Bucky moving grid is used for the antero-posterior view, while a better defined film is obtained in the lateral view if the cone is replaced by a lead diaphragm.

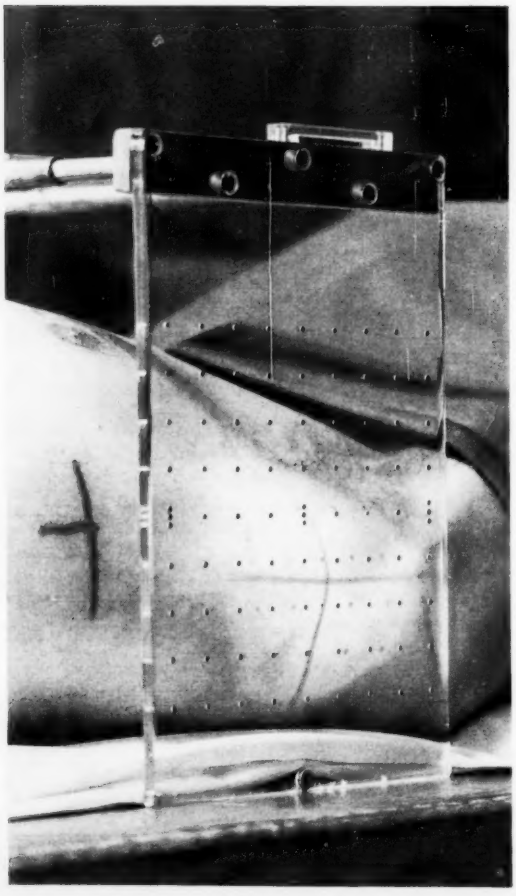

Figure 9. Adjusting the grid pattern to the cross-wires indicating the point of exit of the beam.

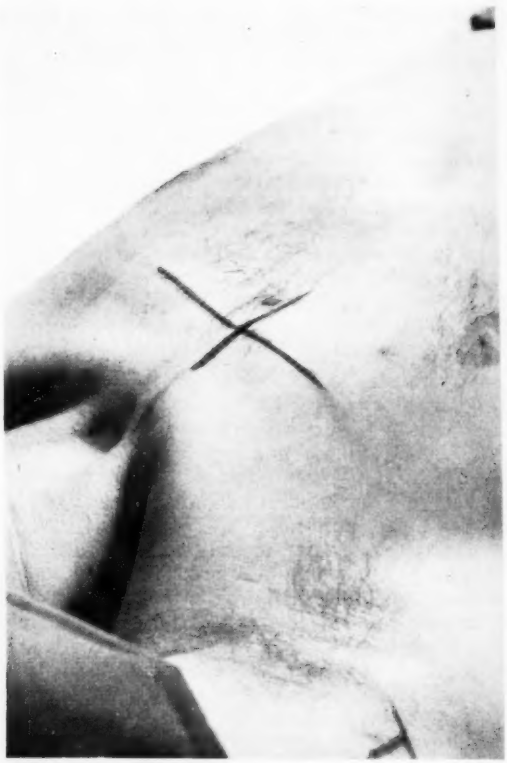

Figure 10. The vertical projection of the cross-wires marked on the skin. The original dot marking the position of the central pin is preserved.

Simple geometry applied to measurements taken from the lateral film relates the magnification of the visualized area, be it tumour or lumen of an organ, to the magnification and known separation of the two grid patterns. Thus the true dimensions of the apparent tumour volume can be measured in the supero-inferior and antero-posterior axes of the patient, and at the same time be located on the grid pattern on the side pieces of the localizer. In the antero-posterior film, the magnification follows from the relation of the height of the focal spot to the height of the tumour above the film. The height of the tumour above the film is obtained by adding the height above the table, as determined from the lateral view, to the measured table-film distance. When the accessory grids are used, it is not necessary to know the tube or table heights and the magnification can be calculated directly from the grid magnifications. This calculation gives the remaining dimension of the apparent tumour volume in the lateral axis and can provide a check on the supero-inferior dimension as measured in the lateral view. The purpose of the central ring and the two lateral lead blobs in the

antero-posterior film is to relate the tumour to the plane midway between the side pieces. The diameter of the visualized or apparent tumour volume has now been measured in three dimensions at right angles and the shape determined in two aspects at right angles. This volume has also been related in space within the bridge. It is important to know the shape in the remaining supero-inferior aspect as this is the plane of rotation. Consequently this shape is plotted out on graph paper by deduction from the known measurements. The next step is to increase this apparent tumour volume in three dimensions to allow for the estimated extent of the invisible tumour. The result may euphemistically be called the true tumour volume and the field size and arcs of rotation, to produce a suitable treated volume to encompass it, can be determined. The term treated volume, as used here, is meant to describe the three dimensional zone of radiation bounded by the isodose shell which is 90% of the dose in the centre.

With the patient and the localizer in the same position on the treatment table, the centre of the tumour is placed in the desired relationship to the centre of rotation by aligning the beam in two directions at right angles. The Theratron is equipped with a light-defining device which simulates the size and position of the beam from an adjustable diaphragm, and projects cross wires at the point of exit. In effect it is a close approximation to a cone and back pointer. The main alignment is done with the beam in a horizontal position and by adjusting the table to register the light beam and the cross-wires to their appropriate position on each grid pattern, the tumour is centred in the antero-posterior and supero-inferior axes. To centre in the remaining lateral axis the counterweight is rotated through 90 degrees to project the cross wires down vertically. The table is then moved from side to side until the cross wires register with the vertical projection of the centre of the tumour, as marked on the sliding cross bar, or top plate.

At this stage there is a choice. If the localizer is removed, the projection of the cross wires marked on the skin and a reading taken of the height of the table, then the localizer is not needed for setting up subsequent treatments. If it is felt that the skin mark of the cross wire would not be in a sufficiently immobile area of skin, then the localizer itself can be used each time for the remainder of the course.

DIMENSIONS

Plastic Side pieces —	19 x 28 x 0.7 cm. with 1 cm. diam. rods projecting 5 cm.
Brass reinforcing cross bars —	19 x 2.5 x 1 cm.
Brass telescoping joining rods —	inner rod 21.5 x 0.9 cm. diameter. —outer tube 30 x 1.3 cm. outside x 0.9 cm. inside diam. —fully open 48 cm., fully closed 31 cm.
Plastic sliding bar —	15.5 x 8 x 0.7 cm., with an engraved centre line, and a central brass bush 1.2 x 0.5 cm. inner, 0.6 cm. outer diam. and a flange 1 cm. diam.
Sliding brass tubes supporting plastic bar —	8 x 1.3 cm. inside x 1.7 cm. outside diam.
Steel pin —	11.5 x 0.5 cm. diam. plus a brass cap.
Top plate —	50 x 5 x 0.35 cm.
Slotted guides, one blind with offset retaining peg —	7 x 1 x 1 cm.
Bottom plate —	50 x 21 x 0.35 cm., with groove, 20.5 x 0.35 x 0.25 cm. deep, reinforcing bar across end of groove 21 x 0.3 x 0.3 cm., and end blocks 4.5 x 2.5 cm. x 1.25 cm., slotted 3.5 x 0.7 cm.
Brass T-peg to fit in groove —	3.5 cm. of 0.3 cm. square bar hard soldered to 1 cm. of 0.3 cm. diam. rod.

Summary

The basic radiotherapeutic concept of closely enveloping a volume of tumour in a homogeneous volume of radiation has not been fully realized in the past due to the practical limitations of fixed field therapy. It is pointed out that circumaxial Cobalt^{60} beam rotation simplifies the problem of producing a homogeneous volume of radiation, the shape of which can be both varied and predetermined. A simple apparatus is described to provide an answer to the problem of determining the shape, size and position of a tumour in three dimensions and then placing it accurately within a pre-determined volume of radiation.

Acknowledgments

Our thanks for the assistance given in developing this method to Dr. T. G. Stoddart, Director, Mr. R. O. Kornelsen, Physicist, Mr. R. H. Archer, Machinist and the Therapy Technicians of the Ottawa Civic Clinic, Ontario Cancer Foundation.

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PREDETERMINED DOSE DISTRIBUTIONS FOR COBALT^{60} CIRCUMAXIAL ROTATION*

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The problem of treatment planning and dose estimation can be tackled in two general ways. The first is to choose an arrangement of fields and to calculate the dose distribution. If the result is not satisfactory the arrangement may be altered and the procedure repeated. By experience we learn which general arrangements produce adequate distributions. The other method of attack is to make a conscious attempt at a predetermined system by plotting certain characteristics about the dose distribution as a function of the variable factors at your disposal. At the same time, it may be convenient to restrict the range of some of the factors. With conventional fixed field therapy, the first method is feasible since the number of field arrangements is relatively limited. However, with the advent of rotating Cobalt beam units where rotation may be carried out over any size of arc and where the field size is continuously variable the number of possible distributions is enormous. Furthermore, the calculation of a rotation distribution is tedious.

The advantages of a predetermined dose system are these:

1. It saves a great deal of time.
2. It puts a greater emphasis on the actual size and shape of the treated tumour volume.

These points will be appreciated by anyone who has tried to plan an arrangement of interstitial radium without the help of Paterson-Parker[1] tables.

A Cobalt^{60} beam lends itself particularly well to pre-planning. The high energy of the radiation and small amount of side scatter tend to make the dose variation near the tumour independent of the size and shape of the patient. Pfalzner and Inch[2] in London, Ontario, have published curves relating the nominal field size to the size of the volume which receives at least 90% of the maximum dose. These curves were for 360° rotation only. In this paper we have extended this system by allowing not only 360° rotation but also rotation in pairs of opposed arcs.

As indicated in Figure 1, the x-axis is the bisector of the arc of rotation, the y-axis is perpendicular to it and is also in the plane of rotation. θ is the total angle of rotation. The z-axis is perpendicular to the page and is the axis of rotation. The treated volume was taken as that region receiving at least 90% of the central dose.

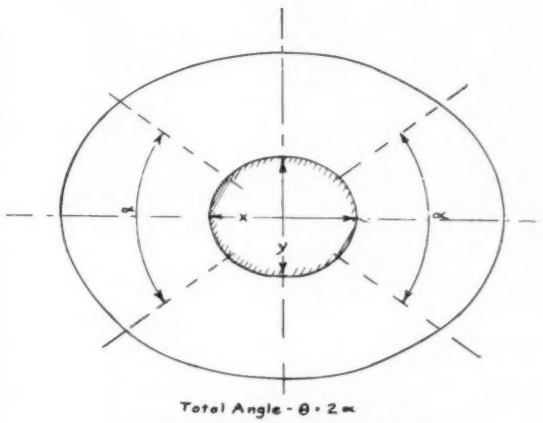

Figure 1. Nomenclature used.

Apparatus

Measurements were taken on an Atomic Energy of Canada "Theratron". The phantom was a water-filled cylinder, elliptical in cross section (22 cm. x 30 cm.). The dose was measured along the x-axis and y-axis for a variety of field sizes and angles of rotation, using a Balwin Farmer Radiological Electrometer with B D-2 condenser chambers.

Results

A typical resulting distribution is shown in Figure 2 for a 6 cm. wide field and 240° rotation. Some idea of the effect of body shape can be obtained from Figure 3. The

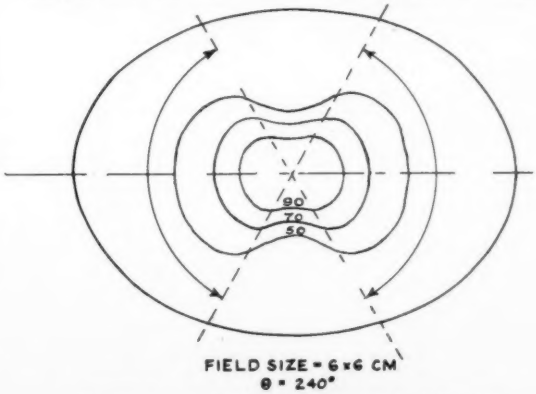

Figure 2. A typical measured distribution using Cobalt^{60} beam.

*Presented at Annual Meeting, The Canadian Association of Radiologists, January 13-17, 1957, Montreal.

†Ottawa Civic Clinic, The Ontario Cancer Foundation.

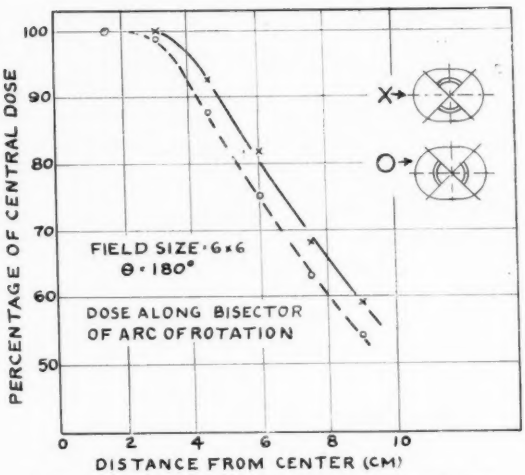

Figure 3. Graph showing the variation of dose along the bisector of the arc of rotation.
——— Minor axis.
..... Major axis.

full line indicates measurements with the minor axis of the ellipse along the bisector of the arc of rotation, and the dotted line with the major axis along the bisector of the arc. The width of the 90% contour differs by about 1 cm. between the two cases. When compiling the final figures the smaller value was used in each case. Hence, any error due to this effect is in such a direction as to give

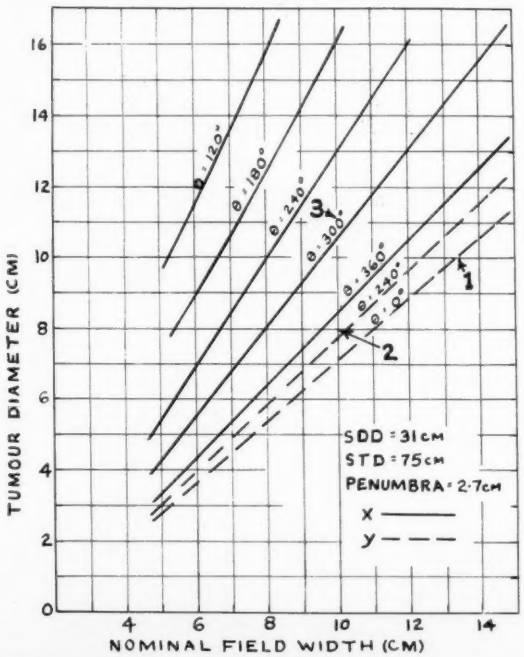

Figure 4. Graph relating the treated tumour volume to field size and angle of rotation, for opposed arcs with Cobalt^{60} beam.

an added margin around the tumour. In Figure 3 the dotted curve cuts the 90% level at a radius of 4.5 cm. This value is plotted on Figure 4 as a tumour diameter of 9 cm. corresponding to a field width of 6 cm. and 180° of rotation.

The results in final form are shown in Figure 4. The full lines relate the field size to the tumour dimension in the x-direction, while the dotted line refers to the y-direction. Since the dose variation along the z-axis is not affected by rotation, the appropriate z-values may be taken from the curve marked $\theta = 0$.

Some remarks should be made about the limitations of the curves.

1. They are strictly valid for central tumours only. Eccentricity of tumour position along the x-axis can be corrected for, by apportioning the treatment time so that each arc contributes an equal dose to the tumour.
2. It was found that the presence of the table top in the beam displaced the region of uniform dosage about 0.5 cm. farther away from the table. The effect of the table is about the same as 3 cm. of extra tissue over that arc.
3. Within 5 cm. of the surface, the curves are not valid since the depth dose does not vary exponentially in this region.

Use of Curves

It is required to treat the tumour shown in Figure 5.

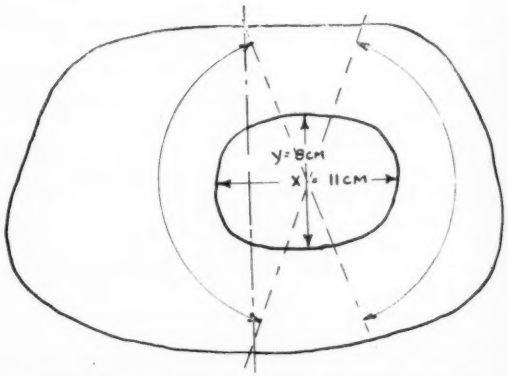

Figure 5. Size and position of tumour discussed in use of Figure 4.

Tumour Dimensions:

x = 11 cm.
y = 8 cm.
z = 10 cm.

Selection of Treatment Factors:

The tumour diameter along the axis of rotation (z-axis) is not influenced by the angle of rotation. We find that the required field height is 13.5 cm. (see pt. 1 Fig. 4). It is now necessary to select a combination of field width and angle of rotation to give the required x- and y-diameters. By inspection we find that a field width of 10 cm. and an angle of 280° satisfies these conditions (see pt. 2 and 3, Fig. 4).

To balance the dose from the two arcs:

Left Side — Mean radius — 14.8 cm.
— Tumour-air ratio (Rt.) — .56
(see Johns et al[3])

Right side — Mean radius — 11.6 cm.
— Tumour-air ratio (Rt.) — .66

$$\frac{\text{Treatment time to left side}}{\text{to right side}} = \frac{(\text{Rt.})r}{(\text{Rt.})_l} = \frac{\cdot 66}{.56} = 1.18$$

Conclusion

It is feasible to devise a predetermined dosage system for Cobalt[60] beam rotation. The chief advantages of such a system are a saving of time, and the fact that it focuses greater attention on the actual size and shape of the treated volume.

Acknowledgment

Thanks are due to Mr. R. H. Archer, for his help in the construction of the apparatus.

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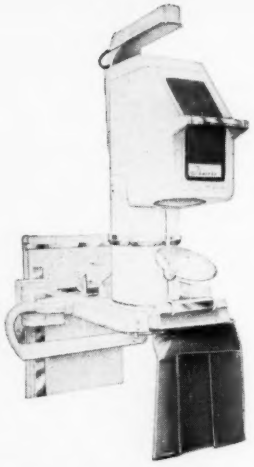

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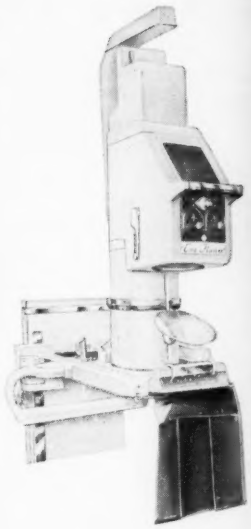

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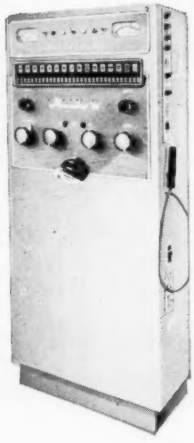

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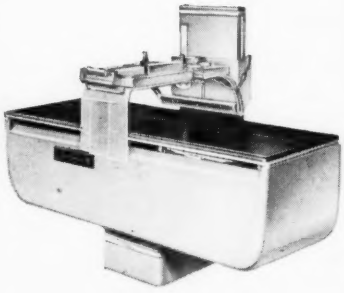

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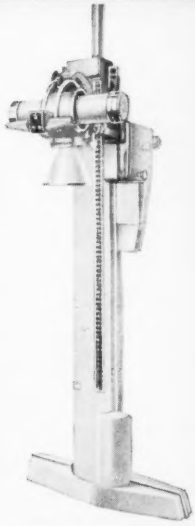

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